Single-Chip Tone Control

For use with the multimedia loudspeaker system

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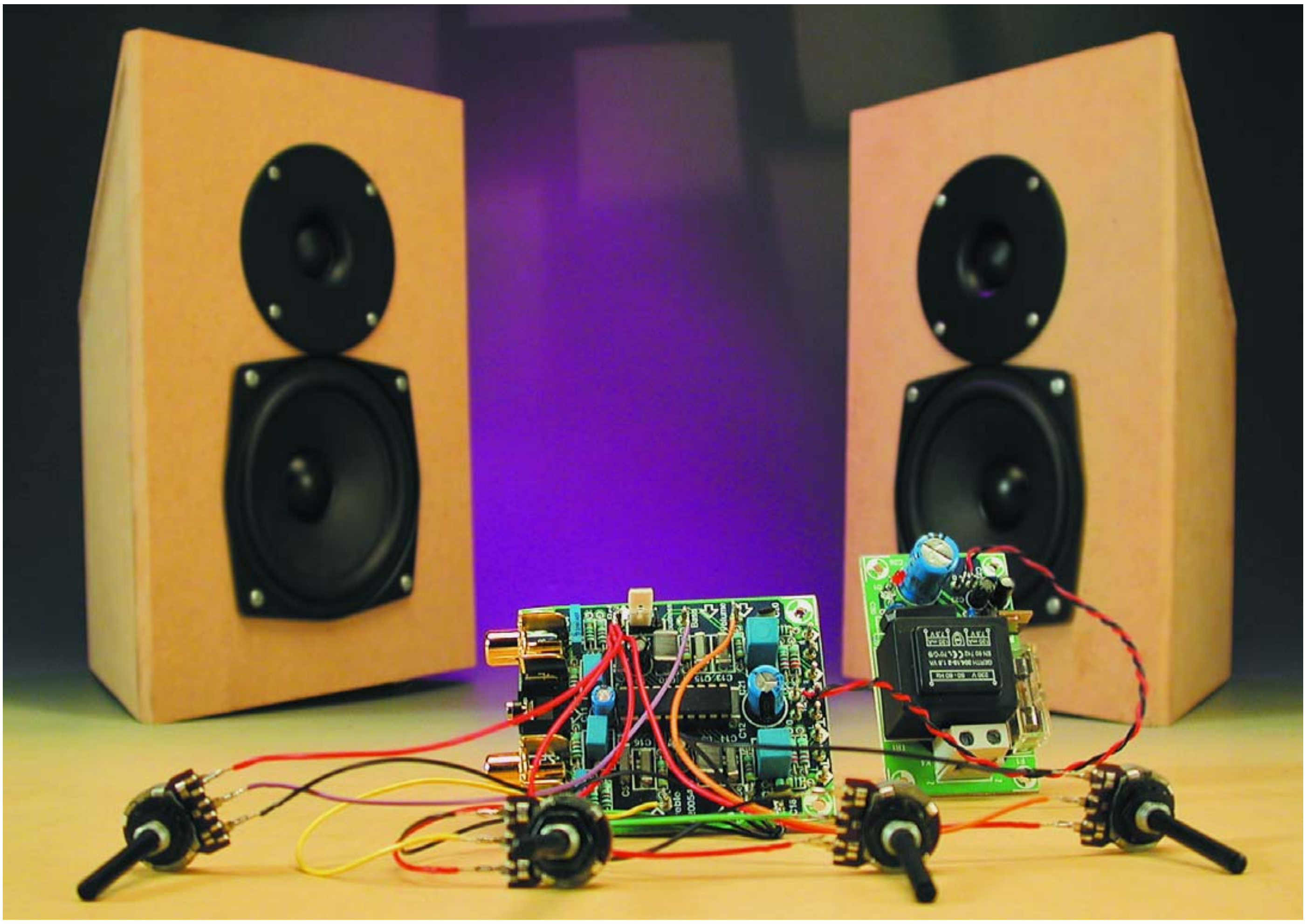
Although our active loudspeaker system was completed with the recently published subwoofer and associated power supply, we have added a little extra for the enthusiast: a compact (standalone) tone/volume/balance control, complete with a stabilised 15 V supply. Our active system must surely rank amongst the most comprehensive of its type.



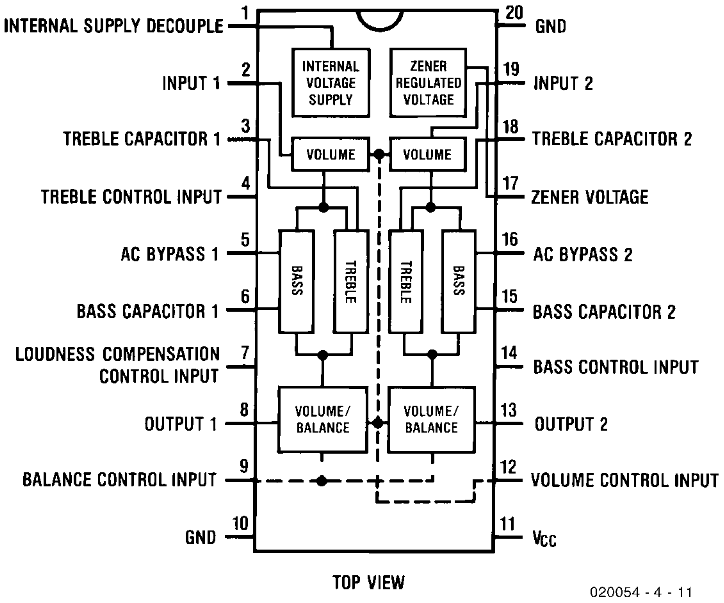


Figure 1. Pin-out and block diagram of the LM1036 (courtesy National Semiconductor).

Something like a tone control is of course not essential for use with most PC loudspeakers. But when the multimedia system is used to play back music then this is a useful extra. Besides, publishing this circuit gives us the satisfaction of knowing that our active system is now really complete.

We've tried to give the tone control as much universal appeal as possible. The circuit can therefore be used on its own as an addition to an existing HiFi system, but at the same time complements our active loudspeaker system as well as possible.

This immediately rules out the use of a discrete circuit. As far as quality is concerned, a well-designed discrete circuit still has the edge on an integrated solution, but the size of such a circuit wouldn't fit in with the rest of the system. For this reason, just as for the amplifiers in the satellites and subwoofer, we searched for a single-chip solution.

The LM1036

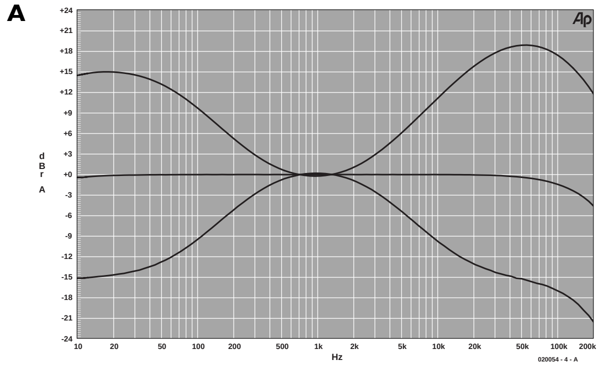
In the past integrated (pre)amplifiers were badly thought of in HiFi circles, although nowadays the quality of these chips leaves little to be desired. Since there has been an increase in demand for better quality Mini systems and car radios, this area has seen an increase in the availability of good quality ICs.

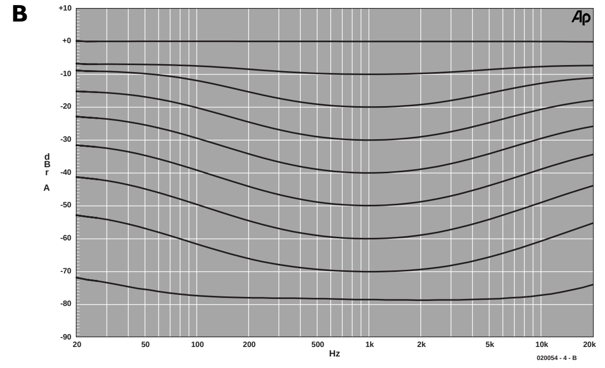
We finally decided on the LM1036 made by National Semiconductor, a 20-pin DIL IC that

Measurements

(All outputs have a 10 kΩ load)

Bass control range (volume –40 dB)	+15 dB / –15dB (20 Hz)
Treble control range (volume –40 dB)	+16 dB / –13dB (20 kHz)
Bandwidth	16 Hz to 70 kHz
Signal to noise ratio	78 dBA (250 mV in)
THD+N (B = 22kHz, 250 mV output)	0.04 % (at maximum gain)
Maximum gain	0.6 dB (≈ 1.07 x)
Maximum input level (250 mV output)	1.93 V (14.43 V supply, THD+N = 0.3 %)
Maximum output level	0.75 V (THD+N = 0.3 %)
Supply voltage range	9 to 16 V
Supply current	46 mA





Response curves:
Graph A shows the frequency response with the bass and treble controls at their extreme settings, with the middle curve showing the response when the tone controls are at their central setting. The volume control was set to –40 dB. We have deliberately shown the response between 10 Hz and 200 kHz, so you can see what happens outside the audio spectrum.
The second graph (B) demonstrates the effect of the loudness compensation. We measured the output level between 20 Hz and 20 kHz at nine different volume levels, with –10 dB (at 1 kHz) between each step. We've used a slightly larger input signal (700 mV) and a band-pass filter so that the range of the volume control could be seen more clearly. The top curve was measured with the volume control at its maximum. The loudness compensation has the strongest effect between –50 to –60 dB. At the bottom curve (0 V control voltage) the output consists mainly of noise and that is the reason why the effect is no longer very noticeable.

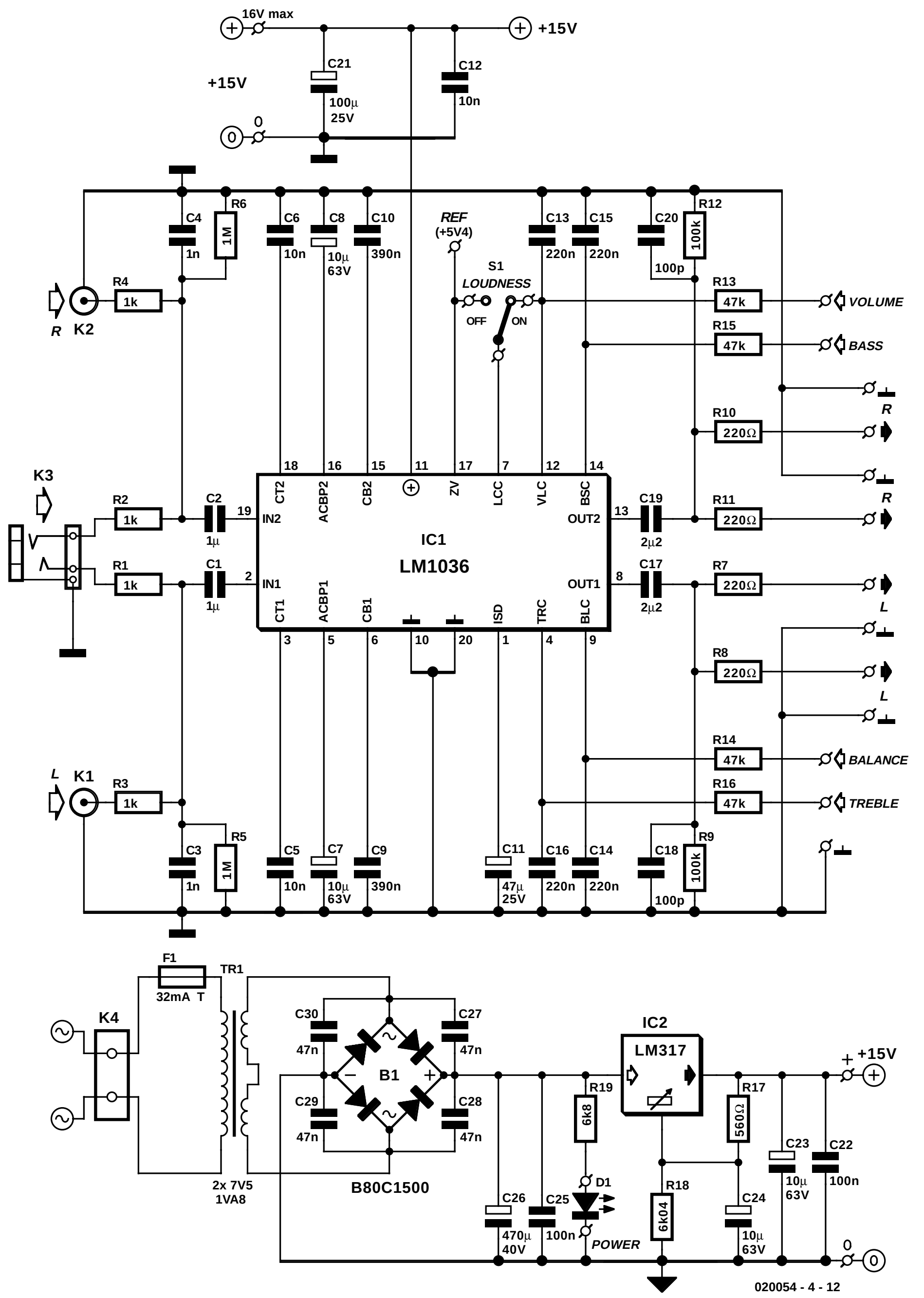


Figure 2. Since all control functions are integrated in IC1, the circuit is an example of simplicity.

contains, with the exception of a handful of external components, a complete stereo volume/tone/balance circuit, and furthermore has a separately switched loudness control. All functions are controlled via DC voltages, so there is no need to worry that mains hum is picked up by the cables between the potentiometers and the PCB. The IC can be used with a supply voltage between 9 and 16 V (a car battery could therefore be used). It has a large volume control range of 75 dB as well as a large tone control range of ±15 dB.

Although the IC doesn't claim to have a high-end performance, its quality is more than sufficient here. The figures given by the manufacturer state that the channel separation is 75 dB, the total harmonic distortion (THD) is 0.06% and the signal to noise ratio is 80 dB. It can be seen that these figures aren't an overstatement when you refer to the section at the end, which shows some measurements and specifications of our prototype.

Figure 1 shows the pin-out and a simplified block diagram of the LM1036. For those of you who are interested, the complete datasheet can be found at www.national.com/pf/LM/LM1036.html

Simplicity itself

The complete circuit diagram in **Figure 2** illustrates how few parts are required for a tone control built around the LM1036. Apart from the IC, there are only a handful of resistors and capacitors, a few input and output connectors and four potentiometers, and that is all.

To make the circuit more versatile we've added a mini jack input (K3) to the usual phono inputs (K1, K2). Only one of these types of input should be used, otherwise the signals will be mixed by R1/R3 and R2/R4 and both sounds will be heard simultaneously.

Each of the left and right channel outputs has a twin set of solder pins on the PCB, making it easier to connect the active 2-way loudspeakers and subwoofer. You are free to choose any type of connector for this.

Four control voltages are required for controlling the volume, treble, bass and balance. These are obtained from four single-ganged linear potentiometers (P1-P4). The ends of these are connected to the internal 5.4 V zener reference (pin 17) and ground, the wipers are connected to VL, BL, BS and TR (pins 4, 9, 12 and 14).

Circuit details

Each control input is decoupled by an RC network (R13-R16, C13-C16). The treble and bass control ranges are set using only a single capacitor per channel. These are C5 and C6 for the high frequencies, and C9 and C10 for the low frequencies.

Another three electrolytic capacitors are required to decouple internally generated voltages (C7, C8 and C11). C1 and C2 decouple the inputs from DC offsets. At the minimum input impedance of the IC (20 kΩ) the roll-off frequency at the input is about 8 Hz. The capacitors at the output (C17 and C19) have a larger value than C1 and C2 because the total load impedance of the active 2-way system and subwoofer is about 6.4 kΩ. C18 and C20 have been added to suppress internal HF oscillations when the output is only slightly loaded.

As mentioned earlier, the IC contains a loudness compensation stage, which gives an increased amplification to lower and higher frequencies at lower volume settings (refer to response curve B). When the 'loudness compensation control' input (pin 7) is connected to the internal zener reference (pin 17), the effect is turned off. The function is turned on by connecting pin 7 to the 'volume control' input (pin 12). We have included a switch for this in the circuit, because we assumed that most constructors would like the facility to switch the loudness function on or off at will. It is also possible to place a 3-pin header on the PCB if you want to keep things simple and have a jumper to set the effect on or off permanently.

Power supply

Although the nominal supply voltage for the LM1036 is 12 V, we decided to use 15 V because the IC can deal with input signals up to 2 V_{rms} at this supply voltage. To spare you the effort of searching for a suitable stabilised 15 V power supply, we've added such a circuit to the design.

We used an LM317 (IC2) for the voltage regulator, because that has a better supply ripple suppression (typ. 80 dB) than standard 78xx regulators. R17 and R18 set the output voltage to 15 V. However, this only applies for the typical values (1.25 V between output and control input, 50 µA adjust current). Due to unavoidable tolerances we found that the output voltage in our prototype was only 14.43 V. If you want to obtain a precise 15 V output you should vary R18 a little (increase its value for a higher output voltage).

The rest of the supply is a standard circuit: a smoothing capacitor (C26) and HF suppression (C25), a bridge rectifier (B1) with HF suppression (C27-C30), a transformer and mains fuse. LED D1 is used as a power indicator.

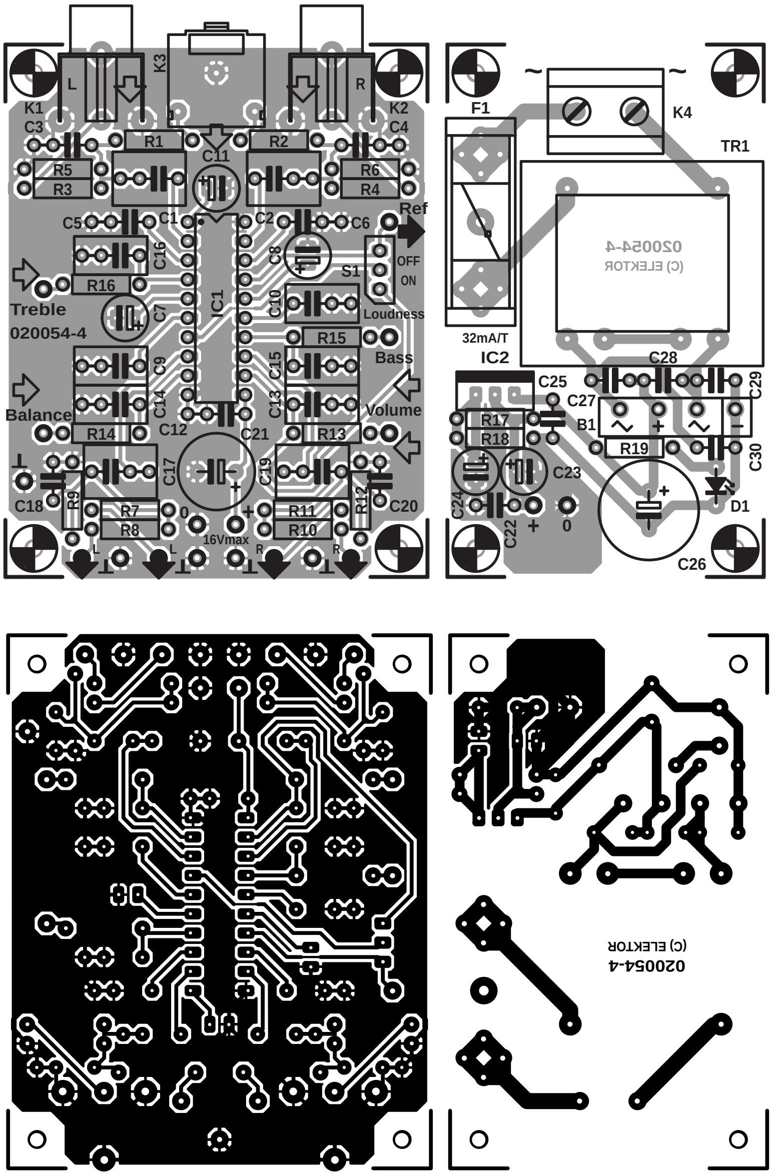


Figure 3. Track and component layout of the PCB. The supply section can be separated from the rest (board available ready-made).

PCB

Figure 3 shows the PCB for the tone control circuit. The power supply section is on the right hand side of the board; this part can be cut from the main PCB if you want to mount it elsewhere in the enclosure. A larger physical separation between the signal processing and supply sections always reduces any possible interference.

The usual rule of mounting components from 'low to high' applies particularly to the power supply section. Should you mount the transformer and bridge rectifier first, you'll find that it becomes very tricky to subsequently solder C27, C28 and C29 into place. A 1.8 VA transformer made by Gerth is given in the parts list, but this has a standard footprint, so other common 1.5 VA types should fit as well.

The construction of the tone control section shouldn't require much time. There aren't that many components and the PCB is well organised. All connections are clearly labelled and positioned logically: inputs on one side, outputs on the opposite side and the connections for the four potentiometers (Treble, Balance, Volume, Bass, Ground (⊥) and Ref) are evenly divided over the remaining sides.

We have already mentioned loudness switch S1. In our prototype we used a pin header and jumper for this. The supply connections have been positioned as close as possible to decoupling capacitors C12/C21 and the outputs. **Figure 4** shows our prototype board.

The choice of enclosure is left up to the reader. There are many enclosures available that can neatly accommodate both PCBs and the four potentiometers. Remember to use a properly isolated mains cable and use a strain relief grommet where the cable enters the enclosure so that terminal block K4 can't suf-

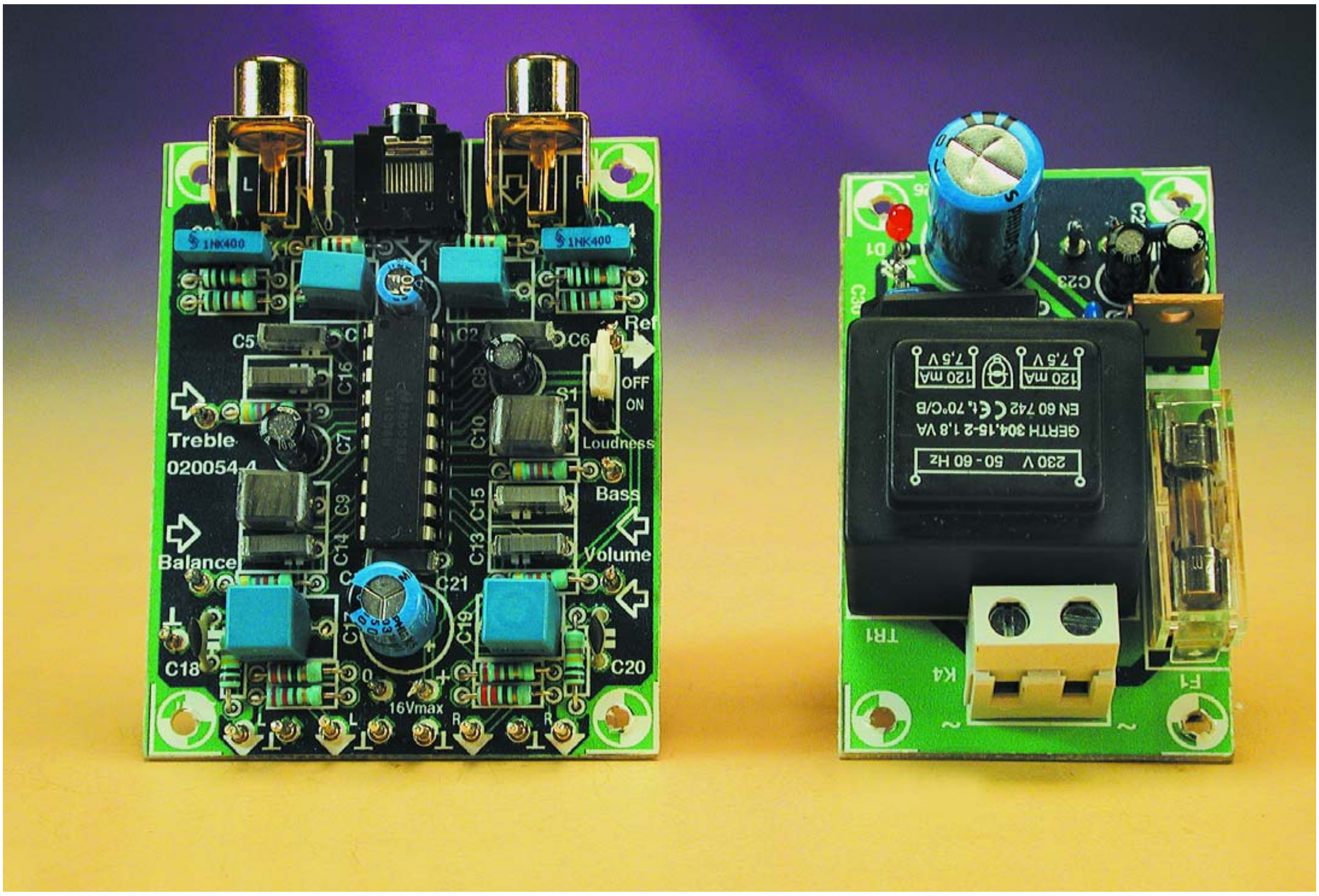


Figure 4. Populating the board should be a fairly easy task.

fer from any mechanical strain. The electrical safety page, which is published regularly in Elektor Electronics, contains many practical guidelines on working with mains voltages. When the circuit has been housed you should apply an identifying label, showing the PCB number and the value of the mains fuse.

A big advantage of this circuit is that the four control inputs are driven by a DC voltage, meaning that the audio signal does not go to and from the potentiometers. In practice this has the benefit that the wiring to the potentiometers doesn't require shielded cable, but that ordinary flexible isolated connecting cables can be used. The wiring is therefore not critical and there is no need to worry about mains hum!

(020054-4)

COMPONENTS LIST

Resistors:
R1-R4 = 1kΩ
R5,R6 = 1MΩ
R7,R8,R10,R11 = 220Ω
R9,R12 = 100kΩ
R13-R16 = 47kΩ
R17 = 560Ω
R18 = 6kΩ04
R19 = 6kΩ8
P1-P4 = 47kΩ linear (mono)

Capacitors:
C1,C2 = 1µF MKT, lead pitch 5 or 7.5mm
C3,C4 = 1nF
C5,C6,C12 = 10nF
C7,C8,C23,C24 = 10µF 63V radial
C9,C10 = 390nF
C11 = 47µF 25V radial
C13-C16 = 220nF
C17,C19 = 2µF2 MKT (metallised plastic), lead pitch 5 or 7.5mm
C18,C20 = 100pF
C21 = 100µF 25V radial
C22,C25 = 100nF ceramic
C26 = 470µF 40V radial
C27-C30 = 47nF ceramic

Semiconductors:
B1 = B80C1500 in rectangular case (80V piv, 1.5A) (~+~–)
D1 = LED, high-efficiency
IC1 = LM1036N (National Semiconductor)
IC2 = LM317 (TO-220 case)

Miscellaneous:
K1,K2 = cinch socket, PCB mount, e.g., T-709G (Monacor/Monarch)
K3 = 3.5-mm stereo jack socket, PCB mount
K4 = 2-way PCB terminal block, lead pitch 7.5mm
S1 = switch, 1 changeover contact
F1 = fuse, 32 mA/T (time lag) with PCB mount holder
TR1 = mains transformer, secondary 2 x 7.5V at 1.8VA (e.g., Gerth type 304.15-2)
PCB, order code **020054-4** (see Readers Services page)